

SHORT-TIME BREADMAKING SYSTEM

by

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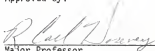
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## INTRODUCTION

Through the 1950's, the predominant breadmaking system in the U.S. was the sponge dough system. Since that time several alternative methods have assumed commercial importance. They may be briefly summarized as follows:

### Continuous Mix

Introduced during the 1950's, the continuous breadmaking systems (i.e., the W & T Do-Maker process and the Amflow process) featured the utilization of a fermented brew. The brew, along with other ingredients, were fed into a high speed, continuous developer that developed the dough and extruded it directly into pans for proofing and baking. Although recognized as an efficient and economical way to make bread, the continuous mix system has declined in commercial importance from a peak of about 40% to roughly 15% of present white bread production. Primary reasons for this decline include consumer resistance to the attributes of the bread (eating properties, flavor, texture) and lack of process flexibility.

### Liquid Ferment

The liquid ferment system was introduced during the latter part of the 1950's and also featured utilization of a fermented brew. However, in this case, the fermented brew, along with other ingredients, were mixed in a conventional (horizontal) mixer. After mixing, the dough was processed the same as for the sponge dough process.

### Short-Time Doughs

Although "no-time" doughs have been known in the baking industry for a long time, there has been a recent increase in usage, particularly in small bakeries. Short-time doughs (actually there are no truly



no-time doughs) involve a single mixing step, followed by little or no bulk fermentation and then processing steps similar to that of sponge-dough methods. Short-time doughs are generally made with warmer doughs, more yeast, and higher oxidation levels when compared to conventional doughs. The doughs will also occasionally contain reducing agents. In spite of the wide utilization of short-time dough processing, relatively little information has been published in the scientific literature.

The purpose of this study was to investigate short-time dough methods of making bread. We wanted to optimize the formulation for a short-time baking system. The rheological changes in doughs during the short-time system was also a major subject of study. In addition, the effects of various reagents, mixing, and rest times on gas retention properties of doughs were investigated.

## LITERATURE REVIEW

### Short-time Breadmaking

In a discussion of short-time breadmaking two concepts are often involved. These are mechanical dough development and chemical dough development. The former involves mixing of dough in a high-speed mixer purportedly to produce changes in the dough similar to the changes occurring during fermentation. Chemical development methods use reducing and/or oxidizing agents to develop the dough. Both methods shorten bulk fermentation time compared to that used with the conventional method.

Sullivan et al (1940) suggested that oxidative agents used by baking industry improves the rheological properties of dough and bread quality through modification involving the sulfhydryl groups and disulfide bonds of wheat flour proteins. Sullivan et al (1961) also

reported that the -SH content of flour is about equally divided between the water-soluble and the gluten proteins.

Potassium bromate is the most commonly used oxidant in breadmaking. Finney et al (1976) reported that by increasing yeast level from 2 to 7.2%, and the bromate level from 20 ppm to 60 ppm, a fermentation time of 70 min will give bread of equal quality to that produced with a conventional straight dough process with 180 min of fermentation.

Ascorbic acid is also an important oxidant used in breadmaking, it appears to be particularly useful in short-time processes. In a 70 min short-time baking system, with a sugar-free formula, the potassium bromate requirement could be reduced by two-thirds when 50 to 100 ppm ascorbic acid was added (Magoffin et al 1977). The use of a combination of low potassium bromate and high ascorbic acid in a sugar-free, high malt breadmaking formula was also reported by Shogren and Finney (1974). Both Meredith (1966) and Marston and Bond (1966) reported a considerable synergism in the action of potassium bromate and ascorbic acid in dough.

In the continuous breadmaking process, ascorbic acid does not act as an improver but is effective in reducing the mixing speed requirement. In the conventional process ascorbic acid does not reduce the mixing requirement (Mauseth and Johnston 1968).

L-cysteine is a fast reducing agent and when used at the proper level, reduces dough development time markedly (Glover 1975). Its value in no-time dough apparently is dependent on the flour quality. Marston and Bond (1966) reported that only stable flours which are difficult to develop adequately in a conventional slow speed mixer yield better bread through the use of L-cysteine.

### Dough Rheology

In short-time breadmaking process, dough rheology is an important factor that should be studied. Frater et al (1960) reported that the rheological properties of dough are directly related to the number of intermolecular disulfide bonds and the rate at which they can interchange with thiol groups. In studying the rheological properties of fermenting and nonfermenting doughs by measuring the internal pressure of dough, Matsumoto et al (1975) reported that oxidizing agents increased, and reducing agents decreased the internal pressure. In nonfermenting doughs, internal pressure decreased during stress relaxation, the decrease was slower in oxidized, and faster in reduced doughs.

Measuring the rheological properties of fermenting doughs by a simple spread test, Hosney et al (1979) reported that yeast was the major ingredient contributing to rheological changes in fermenting doughs and concluded that it was an enzyme system in the yeast which caused the improvement. They also reported that oxidants tended to decrease the spread ratio, and reducing agents had the reverse effect. Ascorbic acid was found to have both an immediate and a time-dependent rheological effect on dough. A combination of ascorbic acid and yeast gave a greater rheological effect than did with the combination of ascorbic acid and bromate or with ascorbic acid alone (Elkassabany and Hosney 1980).

### Oxidative Gelation

Wheat flour contains about 2 to 3% pentosans, 20 to 25% of which are water soluble and form viscous, gummy solutions in cold water. The importance of pentosans in baking was studied by Tracey (1964) and Cawley (1964). The fact that water soluble wheat flour pentosans form a

gel upon reacting with certain oxidizing agents was first reported by Baker et al (1943). Neukom and Markwalder (1978) reported that certain of the arabinoxylan fractions of the water soluble pentosans reacted to form a gel. They also reported that ferulic acid which is esterified to the arabinoxylan chains was involved in the gelation. Hosney and Faubion (1981) reported that a free radical was required for the gel formation and found that the activated double bond of the ferulic acid, not the aromatic nucleus, was involved in the gelation reaction. They concluded that the oxidative gelation is responsible for some, but not all oxidative changes in bread doughs

#### Continuous Mixing

Swanson and Working (1926) demonstrated that bulk fermentation time could be greatly reduced and even eliminated if the dough was modified mechanically through intense mixing. This concept caused the development of continuous mixing process. The "Do-Maker" process was first reported by Baker (1954), which prepared the dough continuously by mechanical development under pressure of a continuous flow of dough ingredients. This process was soon joined by the "Amflow" process (Anonymous, 1958), and these two were the major continuous breadmaking processes in the United States.

The oxidizing agents used traditionally with the continuous mixing process were potassium bromate and potassium iodate. Since azodicarboxamide (ADA) was introduced in 1962 as a flour maturing agent, it has become widely used in the continuous mixing process than potassium iodate as a fast acting oxidant. Therefore, the combination of ADA and potassium bromate is more commonly used in continuous mixing process (Pyler, 1982). Mauseth et al (1967) reported that ascorbic acid acts as a reducing agent instead of an oxidant in the continuous mixing

process. Cysteine, also a reducing agent, has been used to reduce the dough mixing requirement (Henika et al, 1967). Because of the oxygen limiting closed system and the short mixing time used in the continuous mixing process, more oxidizing agents are usually needed than with the conventional mixing system.

CHAPTER I. SHORT-TIME BREAKMAKING BY BATCH PROCESSES

## MATERIALS AND METHODS

Materials

Flour. Ross Mill (Wichita, Kansas) flour (protein 11.6%, moisture 14.7%) that had been malted was used in the baking tests. A second Ross flour (protein 11.6%, moisture 12%) was used in the spread tests and the study of oxidative gelation of doughs.

Yeast. Commercial compressed baker's yeast (70% moisture) and Red Star Insta-Blend active dry yeast (Universal Foods Corporation) were used.

Chemicals. Except for the calcium peroxide, which was obtained from Panipulus Co., Kansas, all other chemicals were reagent grade.

Enzyme active soy flour (EASF). EASF was obtained from Far-Mar-Co., Hutchinson, Kansas.

Enzymes. Lipoxygenase (No. L-3004) and tyrosinase (No. T-7755) were obtained from Sigma Chemical Co.

Commercial short-time dough additives. Twelve commercial additives were coded from CA-1 to CA-12, and used in the baking tests.

Methods

Baking Tests A pup loaf experimental baking procedure was adopted for the preliminary work. The formula was as follows:  
Flour 100% (14% moisture basis), water optimum, salt 1.5%, yeast 2.0%, sucrose 6.0%, shortening 3.0%,  $\text{KBrO}_3$  optimum, NFDM 4.0%. The dough was fermented at  $86^{\circ}\text{F}$ , 90% RH, punched after 105 and 155 min, moulded at 180 min of fermentation, and baked for 24 min at  $218^{\circ}\text{C}$ . Loaves were weighed as they came from the oven, and volume determined by dwarf rapeseed

displacement.

In certain experiments the pup loaf procedure was modified to have a 30 min fermentation time, proof time was determined as the time to give proof height of 7.5 cm for the 30 min procedure. Other formula adjustments included: 0% NFDM, 3% sugar, and 5% yeast.

Spread Test The spread test method reported by Hoskeny et al (1979) was used.

## RESULTS AND DISCUSSION

### Baking Tests

Evaluation of commercial no-time dough additives. The effect of 12 commercial short-time dough additives were examined using the modified pup loaf breadmaking process. In the modified short-time process a 30 min fermentation was used instead of the standard 180 min fermentation. The additive levels used were those recommended by the manufacturer. Results of these tests are summarized in Table 1 and 2. At a 95% confidence level, CA-2, CA-6, CA-7, and CA-11 were not significantly different from the no additive control. CA-4, CA-5, CA-9 and CA-12 all had a limited improving effect on loaf volume. CA-1, CA-3, CA-8, and CA-10 were the most effective additives. They all improved loaf volume by more than 11%. The composition of those additives, as listed on their labels, are given in Table 3. Because of the complexity of the formulas, it was not easy to decide which component or combination of components was responsible for their effectiveness. All of the additives contained  $KBrO_3$  and most of them contained at least one other oxidant. Therefore, we conducted a series of tests to determine the effect of certain oxidants and their combinations in the short-time breadmaking process (Fig. 1 and 2).



Table 1. Loaf volume of breads containing certain commercial additives

Sample	Control	CA-1	CA-2	CA-3	CA-4	CA-5
$\bar{x}$	680.8	775.8	663.8	760.8	722.5	714.2
s	24.4	42.7	13.2	16.6	22.3	13.9

LSD 0.05 = 28.84

n = 6

Table 2. Loaf volume of breads containing certain commercial additives

Sample	Control	CA-6	CA-7	CA-8	CA-9	CA-10	CA-11	CA-12
$\bar{x}$	686.7	653.3	705.0	808.3	711.7	776.7	705.0	731.7
s	10.4	10.4	18.0	14.4	2.9	20.8	8.7	7.6

LSD 0.05 = 19.52

n = 4

Table 3. Components of commercial additives as reported on their labels

Additive	KBrO <sub>3</sub>	KIO <sub>3</sub>	L-Cysteine	Ascorbic Acid	Nono-Ca-Phosphate	(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	CaSO <sub>4</sub>	NaCl
CA-1	x	x			x			
CA-2 <sup>a,b</sup>	x		x		x			
CA-3 <sup>c,d,e,f</sup>	x	x			x			
CA-4 <sup>b,d,g,h,i,j</sup>	x		x	x		x	x	x
CA-5	x				x	x	x	
CA-6 <sup>a,e</sup>	x		x		x			
CA-7 <sup>a,b</sup>	x		x		x			
CA-8 <sup>a,e,i</sup>	x		x	x		NH <sub>4</sub> Cl	x	x
CA-9 <sup>a</sup>	x		x	x	x			x
CA-10 <sup>e,i,j</sup>	x	x		x	x			
CA-11 <sup>d,e</sup>	x	x		x	x			
CA-12 <sup>e,i,k</sup>	x		x		x		x	

## Footnotes for Table 3

- a/ Corn flour
- b/ Whey
- c/ Sorbic Acid
- d/ Flour
- e/ Fungal enzymes
- f/ Barley malt
- g/ Food acids (lactic, acetic, propionic and phosphoric)
- h/ Na casinate, lecithin, polysorbate, dextrose and flour
- i/ Food starch
- j/ Veg. oil
- k/ Ca steroyl lactylate

Fig. 1. Effects of additives on loaf volume.

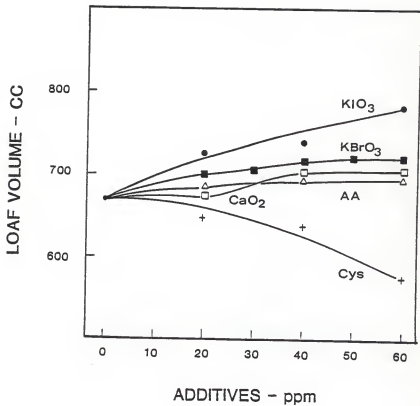
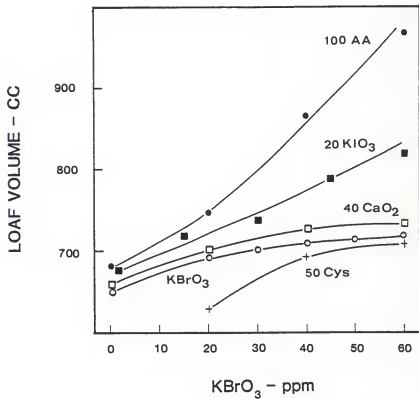


Fig. 2. Effects of combination of additives on loaf volume.





Effects of additives on baking. The addition of oxidants, such as potassium bromate, potassium iodate, calcium peroxide, and ascorbic acid improved loaf volume. When used alone,  $KIO_3$  was the most effective of the four oxidants tested. The improving effects of  $KBrO_3$ , calcium peroxide, and ascorbic acid were similar. Cysteine, a reducing agent, adversely affected loaf volume. At 60 ppm, cysteine reduced loaf volume about 100 cc compared to the control.

Effects of combinations of additives on baking. When 100 ppm ascorbic acid was added along with 40 ppm potassium bromate, the loaf volume was improved tremendously (Fig. 2). Doughs containing 60 ppm bromate and 100 ppm ascorbic acid gave loaf volumes of 940 cc, which is comparable to the loaf volume of bread made with 180 min fermentation, and 30 ppm of  $KBrO_3$ . In addition, very good crumb grains were obtained using that combination of oxidants. A combination of  $KIO_3$  and  $KBrO_3$  also was more effective than  $KBrO_3$  alone. In general, better loaf volumes were obtained at higher oxidant levels; however, the legal limit of 75 ppm for a combination of  $KIO_3$  and  $KBrO_3$  must be considered. The combination of 40 ppm calcium peroxide and potassium bromate had similar effects as that of using bromate alone. At a 95% confidence level, the addition of bromate and the combination of bromate and calcium peroxide were not significantly different. When 50 ppm cysteine was added along with  $KBrO_3$  to doughs, the mixture impaired the effectiveness of  $KBrO_3$ . The adverse effects of cysteine was less when the bromate level was increased.

Using combinations of oxidants also decreased proof time. A combination of  $KBrO_3$  and ascorbic acid was most effective in reducing proof time. With 60 ppm  $KBrO_3$  and 100 ppm ascorbic acid, proof time was about 20 min shorter than that for the control.

Effects of sugar levels. Because of the limited amount of sugar consumed during the short-time breadmaking process, the crust color was dark. Therefore, NFDM was eliminated from the formula and different levels of sugar were tested. With 30 min fermentation time, the loaf volumes produced with 3, 4, and 5% sugar were not significantly different. With 3% of sugar a satisfactory crust color was obtained. Thus, 3% sugar and 0% NFDM were used in the following baking tests.

Effects of yeast levels on baking results and proof time. To study the effects of yeast, 2 to 6% yeast were added to short-time doughs (20 ppm  $\text{KBrO}_3$ ). Loaf volume increased as the yeast level was increased, up to a level of 5% yeast (Fig. 3). Higher levels had no additional effect. With 5% yeast, we obtained a loaf volume about 140 cc larger than that produced with 2% yeast. As expected, when the yeast level increased, proof time decreased (Fig. 4). With 5% and 6% yeast, proof time decreased about 56% and 62%, respectively, compared with the proof time of 2% yeast.

Effects of fermentation time. To examine the effect of fermentation time on loaf volume, 0, 15, and 30 min of fermentation were tested. The adjusted formula included 0% NFDM, 3% sugar, 5% yeast, and 100 ppm ascorbic acid and 60 ppm  $\text{KBrO}_3$ . Loaf volume increased as fermentation time increased up to 15 min (Fig. 5). With fermentation times longer than 15 min, no significant difference in loaf volume was found. The loaf volume produced at 15 min of fermentation was 917 cc which was comparable to the loaf volume obtained with 180 min of fermentation. Proof time decreased as fermentation time was increased (Fig. 6).

Effects of EASF. Enzyme active soy flour (EASF), a source of the enzyme lipoxygenase, was tested at 0.5 and 1.0% levels. As shown in

Fig. 3. Effects of yeast levels on loaf volume.

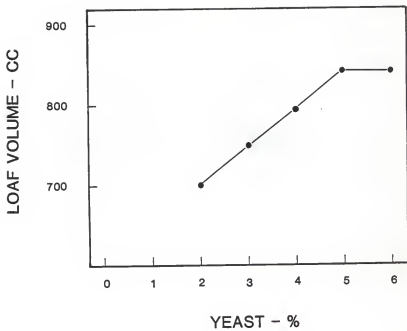


Fig. 4. Effects of yeast levels on proof time.

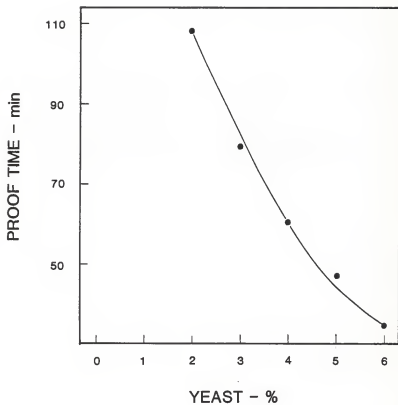


Fig. 5. Effects of fermentation time on loaf volume.

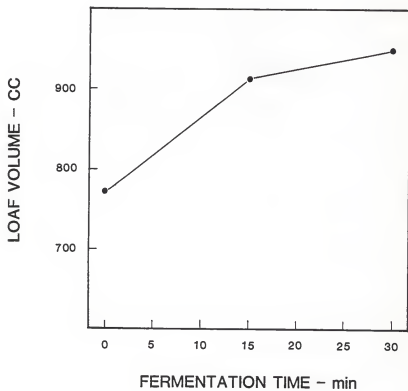




Fig. 6. Effects of fermentation time on proof time.

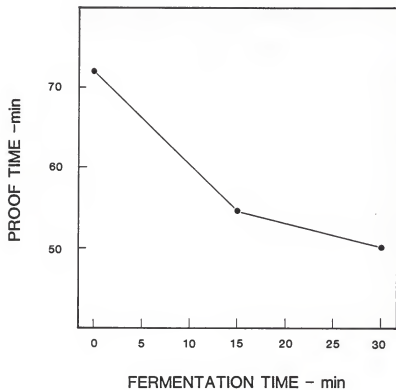


Fig. 7, addition of 0.5% EASF with only 5 min of fermentation gave a loaf volume of 903 cc. Addition of 1.0% EASF with 15 min of fermentation gave a loaf volume of 917 cc. The loaf volumes produced with both 0.5 and 1.0% EASF addition were comparable to the loaf volume obtained with 180 min fermentation. Addition of 0.5 and 1.0% EASF also greatly reduced proof time (Fig. 8). Clearly, the mechanism of EASF should be studied further.

#### Study of Dough Rheology by Spread Tests

To investigate the relationship between dough rheology and its baking performance, the spread test method which was developed by Hosney et al (1979) was used.

Effects of fermentation time. Dough exhibits both elastic and viscous flow properties. A lower spread ratio is indicative of more elastic properties and less viscous flow. It has been reported by Hosney et al (1979) that after fermentation a good dough will give a lower spread ratio. To study the effects of short fermentation time on the spread ratio of dough, the adjusted pup loaf formula was used and the results shown in Fig. 9. We can see that without any fermentation the spread ratio is much higher than for those doughs with 15 or 30 min of fermentation. No fermentation time gave poor loaf volume. Loaf volumes were improved greatly with only 15 and 30 min of fermentation. Thus, the rheological properties of the dough appear to be an indicator of baking performance.

Effects of yeast levels. Doughs with and without yeast showed significantly different physical properties (Fig. 9). Most of yeast's effect on rheological properties was caused by 2% yeast. Increased levels of yeast up to 7% had only minor effects on the spread ratios.

Fig. 7. Effects of enzyme active soy flour and fermentation time on loaf volume.

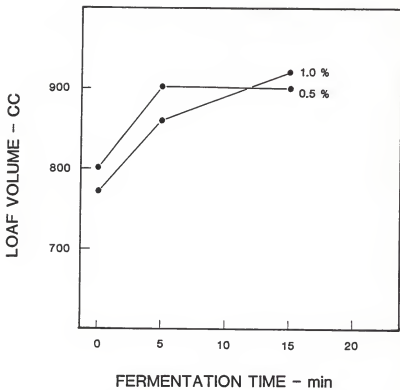


Fig. 8. Effects of enzyme active soy flour and fermentation time on proof time.

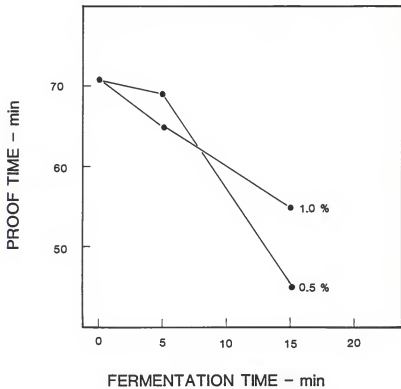
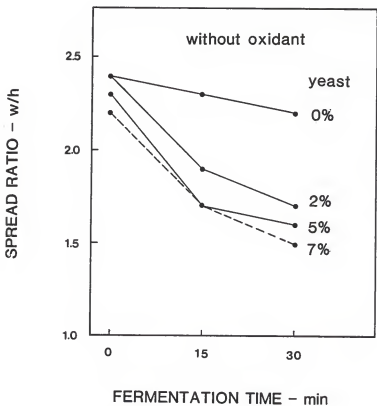


Fig. 9. Effects of yeast levels on dough rheology.





At 30 min fermentation the rheological changes were large, however, at 0 min fermentation, the spread ratios for doughs containing 2, 5, and 7% yeast were similar to that of a water-flour dough (control). Hosney et al (1979) showed that optimum spread ratios for good loaves was about 1.5. To produce bread at 0 min fermentation, the spread ratio of the dough must be decreased to that level. Since at 0 min fermentation yeast alone did not give an optimum spread ratio, a study of oxidants and combinations of oxidants with yeast were undertaken.

Effects of oxidants. In our earlier baking studies, oxidation levels of 60 ppm  $KBrO_3$  and 100 ppm ascorbic acid gave good results. Thus, those oxidant affects on the spread ratio were studied (Fig. 10). Potassium bromate alone did not greatly change dough rheology. A combination of potassium bromate and ascorbic acid or ascorbic acid alone both gave moderate decreases in the spread ratio. However, clearly a lower value for the spread ratio at 0 min fermentation is desired.

Effects of the combination of yeast and oxidants. Effects on dough rheology of combining 5% yeast with oxidants is shown in Fig. 11. The combination of oxidants lowered the spread ratio to 1.3 after 15 or 30 min fermentation. That is a big improvement when compared to the spread ratios of control doughs (2.3 and 2.2). It is also important to note that at 0 min fermentation, a significant decrease in spread ratio was obtained. The results shown in Figs. 9, 10, and 11, show clearly that there was an interaction between yeast and the oxidants. Studying the effect on dough rheology of combinations of yeast and oxidants appears to be a move in elimination of bulk fermentation.

Effects of lyophilized yeast. To study whether the rheological

Fig. 10. Effects of oxidants on dough rheology.

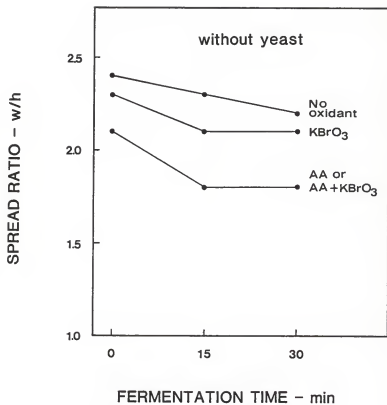
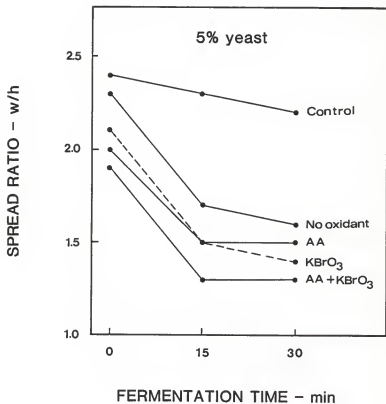


Fig. 11. Effects of the combination of yeast and oxidants on dough rheology.



changes were caused by intact yeast cells or simply by certain enzymes in the yeast, a yeast slurry was lyophilized. The lyophilized powder no longer produced gas showing that the cells were ruptured. The lyophilized product was thus considered as an enzyme source. As shown in Fig. 12, the inclusion of lyophilized yeast, equivalent to 5% of commercial compressed yeast, did not improve the dough rheology. On the contrary, it impaired dough rheology. In comparison to water-flour dough, the spread ratios were higher. When a combination of oxidants and yeast were used, no additional effect above that expected for the combination of oxidants was found. This indicates that the effect on dough rheology by yeast cells requires that they be intact and active. To investigate the possibility that the effect of oxidants was on yeast activity, gas production was measured with a gasograph. Addition of ascorbic acid at 50 and 100 ppm and potassium bromate at 60 ppm, and their combinations gave no significant difference in CO<sub>2</sub> production after two hours as compared to the control (no oxidants). Therefore, it was concluded that the oxidants had no influence on yeast activity.

Effects of EASF. The baking industry has long used enzyme active soy flour at levels of 0.5 to 1.0% based on flour, to bleach carotenoid pigments. It has also been reported (Logan and Learmouth 1955) that soy flour improves dough by increasing the dough's mixing tolerance. The effects of EASF on dough rheology were studied at the 1.0 and 2.0% based on the flour (Fig. 13). Only minor improvements were found at 15 and 30 min fermentation for increments of EASF. However, the results at 0 min fermentation were much better than the control. This indicates that at shorter fermentation time EASF may be beneficial in affecting dough rheology. Again, it was found that the presence of yeast was necessary for EASF to have its effect.

Fig. 12. Effects of lyophilized yeast on dough rheology.



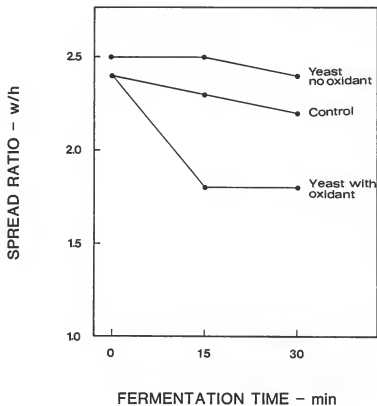
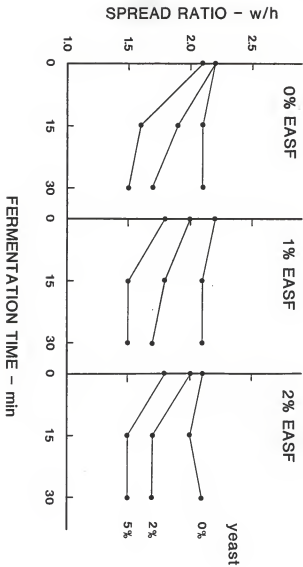


Fig. 13. Effects of EASF on dough rheology.



Effects of tyrosinase. Kuninori et al (1976) reported that mushroom extracts had an oxidative effect on unfermented dough, and thus affected its physical properties. The enzyme, tyrosinase, was reported to be the important factor in the extract. From our baking data, it appeared that 3.7 mg tyrosinase/100 g flour, which gives the same effect as about 60 ppm  $\text{KBrO}_3$ . We added that amount to dough and studied its effects on dough rheology. Tyrosinase in yeasted doughs gave relatively low spread ratios at 0 min fermentation (Fig. 14).

Effects of cysteine and  $\text{KIO}_3$ . Substances that contain sulphydryl groups, such as cysteine, have been reported to reduce mixing requirements. Their effect on dough rheology was studied by adding cysteine at levels of 10, 25, and 50 ppm in combination with EASF at levels of 0, 0.5, 1.0, and 2.0%. Spread ratios were measured at 0 min fermentation (Table 4). All combinations gave relatively high spread ratios. Those results supported our earlier baking results, which showed that addition of cysteine produced poor loaves. Thus, sulphydryl groups containing substances did not give good effects on dough rheology. The effects of fast acting oxidants, such as  $\text{KIO}_3$ , were studied for their effects on dough rheology at 0 min fermentation. With the combination of 5% yeast,  $\text{KIO}_3$  gave good improvement by decreasing the spread ratio from 2.3 (0 ppm) to 1.8 (30 ppm). Therefore, fast acting oxidants appear to have good potential for improving the rheological properties of dough fermented for short times.

Effects of pH on dough rheology. Dough pH's were adjusted to 5.1 and 5.5 by addition of lactic acid. At 0 min fermentation, spread ratios were measured. The results show no significant difference in spread ratios. This indicates that although pH changes as dough is fermented, it is not the important factor which affects dough rheology.

Fig. 14. Effects of tyrosinase on dough rheology.

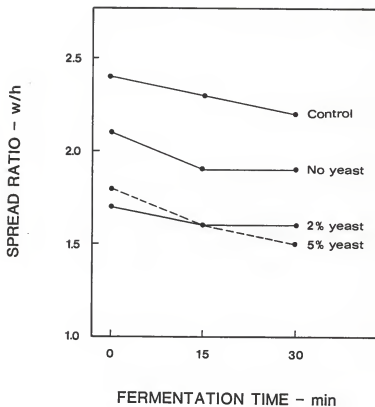


Table 4. Effects of cysteine and EASF on dough rheology

Cysteine	EASF			
	0.0%	0.5%	1.0%	2.0%
10 ppm	2.6	2.4	2.5	2.3
25 ppm	3.8	4.0	4.0	3.9
50 ppm	5.1	4.9	4.8	4.5

yeast: 0%

Effects of remixing. Primary baking results indicate that remixing of a fully fermented dough is known to damage the dough so that it will not produce a good loaf of bread. To study the rheological changes in remixed doughs, doughs both with and without oxidants were studied at 15 and 30 min fermentation (Fig. 15). Remixing impaired dough rheology. The presence of oxidants prevent some of the damage, however, without oxidants dough rheology was badly affected.

Study of Dough in a Remix System

To study the oxidative gelation phenomenon in dough, doughs were mixed for 2 min (premix), allowed to set for 60 min then mixed to optimum (remix). After the remix, the doughs were fermented for 0, 5, 10, and 15 min, moulded, proofed, and baked. Yeast (5%) and oxidants (100 ppm ascorbic acid, 60 ppm  $KBrO_3$ ) were added, respectively, or in combination at different stages of mixing. It was hoped that such a scheme would give insight into the biochemical changes occurring in doughs.

Comparison of a 60 min rest and no-rest. Comparison of baking results for doughs that had been allowed to rest for 60 min, then mixed with yeast and oxidants and doughs with no-rest time, were essentially identical (Fig. 16). This indicates that no additional oxidative effects were obtained when doughs rested for 60 min, if both yeast and oxidants were added at the remixing stage. However, the addition of the combination of yeast and oxidants at the premix stage rather than at remix stage produced quite different results (Fig. 16). A rapid and steady increase in loaf volume was obtained as a function of fermentation time, when yeast and oxidants were added at the remix stage. Thus, a substantial improvement in loaf volume was observed at 0 min fermentation when the yeast and oxidants were added in the premix. The loaf volume was



Fig. 15. Effects of remixing on dough rheology.

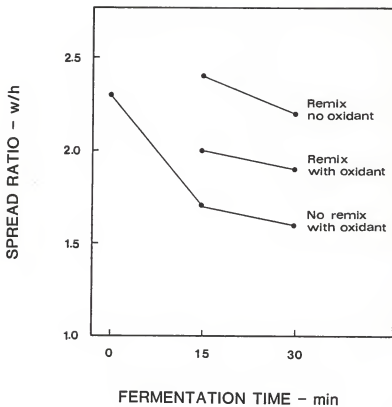
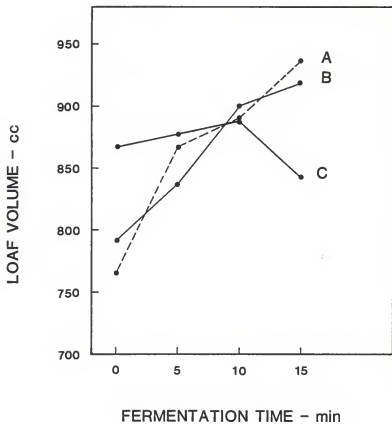


Fig. 16. Effects of 60 min rest and no-rest doughs.

- A -- yeast and oxidants added in remix stage.
- B -- no resting.
- C -- yeast and oxidants added in premix stage.



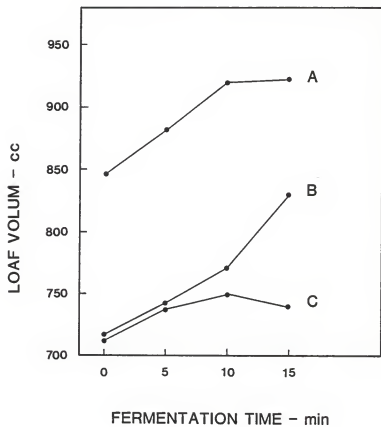
about 100 cc greater than when the yeast and oxidants were added at the remix stage. Thus, yeast and oxidants produced beneficial effects on the dough during the 60 min of rest. The reason for the apparent decrease in loaf volume after 10 min fermentation is not clear.

Effects caused by yeast and oxidants. To study whether the improving effects during the rest period was contributed by yeast, oxidants, or their combination, the yeast and oxidants were individually added at different stages of mixing (Fig. 17). Clearly, adding the oxidants in the premix and yeast in the remix gave much better loaf volumes than did the opposite addition. At 0 min fermentation an increase of 135 cc was obtained when  $\text{KBrO}_3$  was added at the premix stage. Comparing curves B and C in Figure 17, both doughs contained no oxidants, but B had the yeast added at the premix stage and curve C had the yeast added at the remix stage. After 0 and 5 min of fermentation the results were similar. This may indicate that the oxidative changes brought about by the yeast during the 60 min of resting is weak and was destroyed during the remix. Therefore, curve B shows the same results as obtained when the yeast was added in the remix. Such an explanation would also explain the results of curves A in both Fig. 16 and 17. If the effects caused by the yeast were destroyed, only oxidants effects can be demonstrated. As shown in curves B and C (Fig. 17), different baking results were obtained after 15 min fermentation. This indicates that the addition of yeast at the premix stage does have an effect, if the dough is allowed to ferment for 15 min after remixing.

Effects of different levels and combinations of  $\text{KBrO}_3$  and ascorbic acid. Different levels of  $\text{KBrO}_3$  (30, 60, and 90 ppm) and ascorbic acid (50, 100, and 150 ppm) and their combinations (30 ppm  $\text{KBrO}_3$  + 50 ppm A.A., 60 ppm  $\text{KBrO}_3$  + 100 ppm A.A., and 90 ppm  $\text{KBrO}_3$  + 150 ppm A.A.) were

Fig. 17. Effects caused by yeast and oxidants.

- A -- oxidants added in premix, yeast added in remix.
- B -- no oxidant, yeast added in premix.
- C -- no oxidant, yeast added in remix.



studied for their oxidative effects on the dough. As shown in Figs 18, 19, and 20, increasing the  $\text{KBrO}_3$  levels gave larger loaf volumes. However, no improvement was found by increasing the ascorbic acid levels. With the combination of oxidants, 60 ppm  $\text{KBrO}_3$  + 100 ppm A.A. was found to give the best results.

Effects of fast acting oxidant. Because higher levels of  $\text{KBrO}_3$  gave good improvements on loaf volume at 0 min fermentation, we wondered if fast acting oxidants would give better improvements. Increasing the  $\text{KIO}_3$  level to 20 ppm gave a good improvement in loaf volume at 0 min fermentation (Fig. 21). However, when the level was increased to 30 ppm the volume was lower and did not increase with fermentation time. Thus, the combination of 60 ppm  $\text{KBrO}_3$  and 100 ppm ascorbic acid gave better results than obtained with fast acting oxidants.

Effect of adding  $\text{KBrO}_3$  in premix and ascorbic acid in remix. To investigate, if the addition of  $\text{KBrO}_3$  and ascorbic acid separately, in different stages of mixing would give different effects, 60 ppm  $\text{KBrO}_3$  and 100 ppm ascorbic acid were added in the premix and remix stages, respectively. The results (Fig. 22) showed no significant difference between the results when both  $\text{KBrO}_3$  and ascorbic acid were added in the premix stage and that when  $\text{KBrO}_3$  was added at the premix stage. Thus, it did not matter when the ascorbic acid was added. It is the  $\text{KBrO}_3$  that is responsible for the improvement during the 60 min of resting. It appears that  $\text{KBrO}_3$  requires time for its effect.

Comparison of different rest times on oxidative effects. There was essentially no significant difference in loaf volume for doughs fermented at 0 min after resting with oxidants for 15, 30, 60, and 120 min. This suggests that the oxidative effects caused by the oxidants might have



Fig. 18. Effects of 30 ppm  $\text{KBrO}_3$ , 50 ppm ascorbic acid and their combination.

Oxidants added in premix, yeast added in remix.

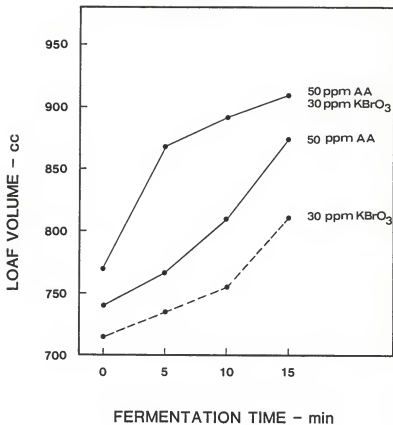


Fig. 19. Effects of 60 ppm  $\text{KBrO}_3$ , 100 ppm ascorbic acid and their combination.

Oxidants added in premix, yeast added in remix.

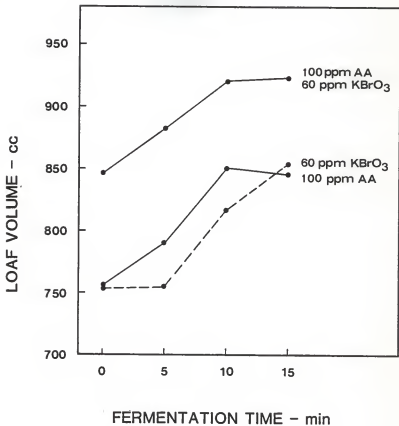


Fig. 20. Effects of 90 ppm  $\text{KBrO}_3$ , 150 ppm ascorbic acid and their combination.

Oxidants added in premix, yeast added in remix.

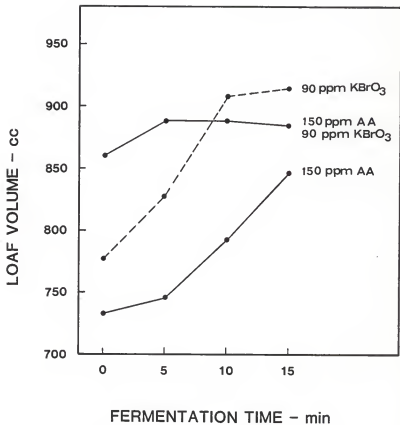


Fig. 21. Effect of 10, 20, and 30 ppm  $\text{KIO}_3$ . Oxidants added in premix, yeast added in remix.

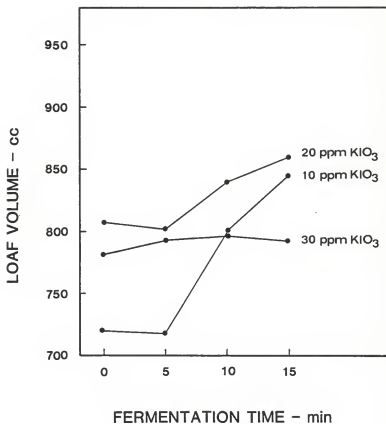
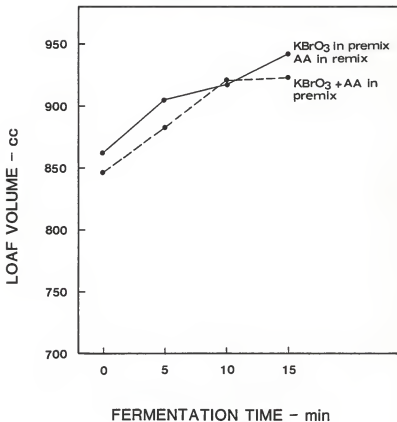




Fig. 22. Effect of ascorbic acid added in different stages of mixing.



been finished within 15 min.

Effect of different yeast levels. To study yeast levels, 3, 5, and 7% of yeast were used and as shown in Fig. 23, with 0 and 5 min of fermentation, no difference was found with different levels of yeast, yet after 10 min of fermentation, the results obtained with 5% yeast were better.

Effect of yeast added alone at different stages of mixing. After 60 min of resting, loaves with greater volumes were produced (curve B) (Fig. 24), compared to the dough with no resting (curve C). The reason for the large difference between curves A and B, after 15 min of fermentation is not clear. It is clear from these results that something is occurring during the 60 min rest not related to the effect of yeast or oxidants.

Effects of EASF. The effects of EASF, with and without oxidants, were studied. The combination of EASF (1%) and oxidants gave better loaf volumes than obtained with the addition of oxidants alone. However, without the addition of oxidants, the loaf volumes were very low (Fig. 25).

#### CONCLUSIONS

The optimized formulation for short-time breadmaking was: flour 100%, yeast 5%, sugar 3%, salt 1.5%, shortening 3%, water optimum, and an oxidation system containing 100 ppm ascorbic acid plus 60 ppm  $\text{KBrO}_3$ . With that formulation, it was possible to reduce the fermentation time in the range of 15 to 30 min and produce bread with good volume, and crumb grain. The total time, from the beginning of mixing till the end of baking, was about 100 min. When compared with the conventional processing time (about 4.5 hrs) time was cut by 63%.

Fig. 23. Effect of different yeast levels.

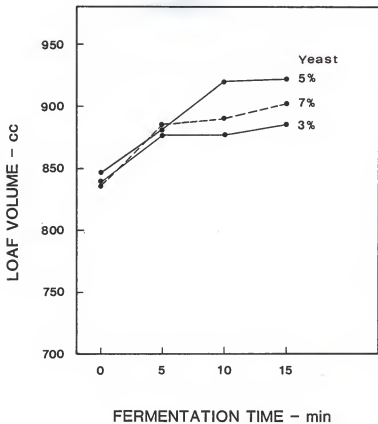


Fig. 24. Effect of yeast added alone at different stages of mixing.

Without oxidants

- A -- yeast added in premix.
- B -- yeast added in remix.
- C -- no resting.

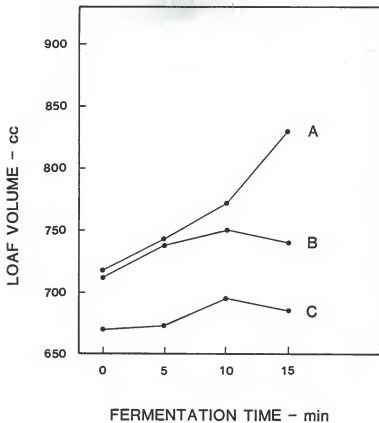
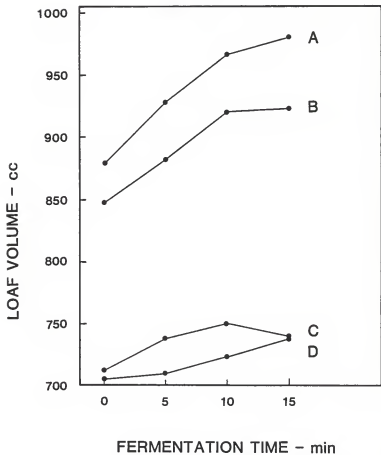


Fig. 25. EASF effects produced with and without oxidants.

- A -- oxidants added in premix, yeast and EASF added in remix.
- B -- oxidants added in premix, yeast added in remix.
- C -- no oxidant, yeast added in remix.
- D -- no oxidant, yeast and EASF added in remix.





In studying the rheological changes of dough in short-time bread-making systems, yeast and oxidants were found to interact. When used in combination, optimum spread ratios (a measure of viscous flow) were obtained after 15 min of fermentation. Even at 0 min fermentation the spread ratio was greatly improved by the addition of yeast and oxidants.

Tyrosinase, EASF, and  $KIO_3$  were also found to improve dough rheology when used in combination with yeast at 0 min fermentation. However, the addition of cysteine (often used in commercial short-time improvers) produced a negative effect on dough rheology. Changing the pH of doughs was found to have no effect on their rheological properties.

In an effort to learn more about the effects of the yeast and oxidants on the gas retention properties of doughs, a premix system was used. It made no apparent difference when yeast or ascorbic acid were added. However, it was important when  $KBrO_3$  was added at the premix stage. When added, it increased the loaf volume at 0 min fermentation about 100 cc. The 60 min of rest between the premix and remix also were responsible for high loaf volume, even when no oxidant or yeast was added at the premix stage.

When levels of  $KBrO_3$  above 60 ppm were used higher loaf volumes were obtained, however, the combination of 100 ppm ascorbic acid and 60 ppm  $KBrO_3$  was the most effective oxidation system. Adding fast acting oxidant such as  $KIO_3$ , also gave an improving effect at levels up to 20 ppm  $KIO_3$ . At higher levels of addition, the results were poorer (lower loaf volume obtained than 20 ppm). Optimum yeast level was found to be 5%.

## CHAPTER II. SHORT-TIME BREADMAKING BY CONTINUOUS MIXING PROCEDURE

## MATERIALS AND METHODS

### Materials

The flour used was a commercial bakers flour obtained from Ross Mills, Wichita, Kansas. The flour contained 11.6% protein and had been malted. The yeast used was Red Star Insta-blend active dry yeast from Universal Foods Corporation, Milwaukee, Wisconsin. The calcium peroxide was obtained from Paniplus, Kansas City, Kansas and the enzyme active soy flour from Far-Mar-Co., Hutchinson, Kansas. All other chemicals were reagent grade.

### Methods

Preparation of Continuous Mix Doughs. Continuous mix doughs were prepared with a Wallace and Tiernan Do-Maker Laboratory Mixer. The procedure involves assembling a pre-mix comprising the liquid ferment (where applicable), flour, shortening, milk, sugar, and other ingredients. The pre-mix is blended on a Hobart A-200 mixer, fitted with a 12-qt. bowl, for 45 seconds on speed 1 and 15 sec on speed 2. The pre-mix is then placed in the loading cylinder of the Do-Maker located directly over the developer bowl. A hydraulically operated piston forces the mixture from the loading cylinder into the developer bowl at a constant rate. This piston controls the flow of materials through extrusion and simulates the pumping action of large commercial units. Piston travel is variable depending on the desired production rate. Dough development takes place as the mixture passes through the developer bowl. The impeller speed is variable and controlled to obtain optimum dough development at the point of extrusion. The developed dough is continuously extruded through the orifice, located at the bottom of the developer bowl directly into baking pans.

1. Continuous Mix Dough - Liquid Ferment

## a. Liquid Ferment

<u>Ingredient</u>	<u>Bakers %</u>	<u>Batch basis*</u> <u>g.</u>
Water	60.0	4500
Sugar	2.0	150
Nonfat dry milk	2.0	150
Yeast (instant dry)	1.4	104
Salt	2.0	150

\*Based on 7500 g flour

## b. Method of preparing liquid ferment

- i. Prepare water bath at 86°F
- ii. Add make-up water at 86°F into each ferment container. Add dry ingredients, place in water bath and stir to incorporate.
- iii. Add yeast on schedule to start test.
- iv. Stir at medium speed for 2 hr.

## c. Preparation of dough

<u>Ingredient</u>	<u>Bakers %</u>	<u>Batch basis</u> <u>g.</u>
Flour	100	7500
Shortening	3	255
Oxidant, ppm	60 bromate, 30 ADA	
Water	8	600
Ferment (as above)		
Sugar	5	375

Method of preparing pre-mixed doughs:

1. Transfer ferment to mixing bowl on schedule. Add flour, shortening, water, and oxidation solution in rapid order.

2. For 12 qt. bowls, use a hook at low speed for 45 sec. and med. speed for 15 sec.
3. Transfer pre-mixed dough to mixer cylinder and proceed from section 4 in the following paragraph.

#### Operating Procedure for Continuous Laboratory Mixer

1. Prior to run, check recorder, pump and developer power supply. Check air and cold water supply. Check to see that developer speed is set at 200 r.p.m. Adjust if necessary with motor running. Fill water reservoir and prime pump. Check recorder ink and paper supply.
2. Disassemble unit. Just prior to first run of the day, temper mixing bowl, impellers and cover plate in water at 110°F.
3. Starting 5 min prior to scheduled pre-mix time, dry tempered parts and reassemble unit. Leave cover and piston off.
4. Prepare pre-mixed dough as described above and add to cylinder. Expel trapped air from dough and shape dough surface to be high around the sides and low in the center.
5. Attach cover and piston. Leave plunger loose. Attach cold water hose (first to cylinder and then to supply fitting). When plunger begins to rise, disconnect cold water hose from supply and attach to pump outlet. Secure plunger and start pump.
6. Jog impellers frequently (about 1/2 sec. per 5 sec.) until dough begins to flow from outlet.
7. Start developer and run at 200 r.p.m. for 45 sec. Reduce speed quickly during next 15 sec. to operating speed (125 r.p.m.). Run for 1 min to reach equilibrium before panning dough.

## B. Pan dough.

2. Continuous Mix Dough - No-Time

## a. Formulation

<u>Ingredient</u>	<u>Bakers %</u>	<u>Batch basis g.</u>
Flour	100.0	7500
Sugar	6.0	450
Shortening	3.0	225
Nonfat dry milk	2.0	150
Salt	2.0	150
Yeast (instant dry)	1.4	104
Oxidant, ppm	60 bromate, 15 ADA	
Water	68.0	5100

## b. Preparation of Dough

The pre-mix was made as described above (except no liquid ferment was utilized).

The dough was developed in the Do-Maker as described above in Operating Procedure for Continuous Laboratory Mixer, paragraph 4.

Comparison of No-Time Continuous Bread with Conventional (Brew) Continuous Bread. The sensory evaluation of bread was with a triangle test. Bread crumb samples (2" x 1.5") were served in coded zip lock polyethylene bags to 32 judges. Each judge received three coded samples: 16 judges tested two samples from bread prepared by one method and one sample from bread prepared by the second method. The other 16 judges received one sample from bread prepared by method 1 and 2 samples from bread prepared by method 2. The order of the three samples was randomized for each judge and the order in which each judge should taste the samples was indicated by code number. The random numbers were generated

by statistical methods.

The score sheet used was as shown on the next page.

To measure firmness a Voland-Stevens-LFRA Texture Analyser (Volland Corp., P. O. Box 1002, Hawthorne, N. Y. 10532) equipped with a Sargent-Welch Recorder, Model XKR (Sargent-Welch Scientific Corp.) was used. Bread slices were compressed 10 mm at the rate of 2 cm/min and the force was recorded at a chart speed of 5 cm/min.

## RESULTS AND DISCUSSION

### Formulation and Procedure

The use of the formulation developed for the small scale no-time procedure gave a rather poor loaf of bread with the continuous procedure. The formulation was as follows: yeast (5%), salt (2%), sugar (3%), shortening (3%), and an oxidant system of 60 ppm  $\text{KBrO}_3$  and 100 ppm ascorbic acid. The 5% yeast was dry yeast added at 5% equivalent compressed yeast. The continuous procedure was optimized for water (68%) and mixer r.p.m. (150).

In most short-time systems the oxidant system used is of paramount importance. Thus, the oxidant system was investigated first. As shown in Table 5, doughs containing ascorbic acid or a combination of ascorbic acid and  $\text{KBrO}_3$  were not superior in the continuous system as we had found with the batch no-time process. Literature reports have also indicated that ascorbic acid was not effective as an oxidant in continuous breadmaking systems. Presumably, the closed mixing system does not provide enough oxygen to convert the ascorbic acid to dehydroascorbic acid. It is known that dehydroascorbic acid is the active oxidation reagent. Potassium bromate alone will give a loaf with reasonable



## 'SENSORY EVALUATION OF BREAD'

You are provided with three samples of bread crumb. Two of them are from the same bread and the third is from a different bread. On the basis of their EATING QUALITIES (flavor, texture, taste...etc.), identify the different samples.

Code

Check different sample

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---

and tell us what EATING QUALITIES made it different for you.

Indicate the degree of difference between the duplicate samples and the different sample.

SLIGHT 

---

MODERATE 

---

MUCH 

---

EXTREME 

---

Comments:

Table 5. Effect of various oxidants and their combinations on continuous procedure bread

Oxidant System	Specific Volume cc/g	Crumb Grain
None	4.26	Very Open
KBrO <sub>3</sub> , 60 ppm	5.19	Open
Ascorbic Acid, 100 ppm	4.58	Open
Azodicarbonamide (ADA), 15 ppm	4.97	Good
Azodicarbonamide (ADA), 25 ppm	5.42	Good
Azodicarbonamide (ADA), 50 ppm	5.12	Good
ADA (15 ppm) + KBrO <sub>3</sub> (60 ppm)	5.23	Excellent
Ascorbic Acid (100 ppm) + KBrO <sub>3</sub> (60 ppm)	5.20	Open

volume, but the grain is relatively open. Azodicarbonamide (ADA) is a rapid acting oxidant that is widely used in the baking industry. ADA is a dry powder that stores well. Most US mills treat bread flour with ADA. ADA in the continuous procedure gave bread with good volume and good grain. The doughs containing a combination of ADA (15 ppm) and  $\text{KBrO}_3$  (60 ppm) gave loaves with excellent grain.

While the use of a fast acting oxidant, such as ADA, gave loaves with good volume and grain, there were two remaining problems with the bread. First, the bread had a tendency to shrink upon cooling. This phenomena is called keyholing in the baking industry and occurs often in the no-time bread. The keyholing was not consistent but appeared to be associated with using higher levels of ADA. The second problem was a dull, light brown crust color of the bread produced.

In an effort to improve the appearance of the bread, a number of formula changes were investigated. The level of sugar was increased from 3% to 6%. As a result of the higher sugar level, the loaf volume increased slightly and the appearance of the loaf was slightly better. The second formula change was the addition of 2% nonfat dried milk. Milk is often added to bread to both improve its appearance and to improve the nutritive value of the bread. The crust color was improved by the milk in the formula. A third additive (0.5% glutamic acid) was found to be just as effective as nonfat dried milk as far as improving crust color was concerned. Our standard formula was modified to contain 6% sugar and 2% nonfat dried milk.

Other fast acting oxidants such as calcium peroxide and potassium iodate were studied. In general they were found to give results similar to that obtained with azodicarbonamide. Potassium bromate has been

reported to act as a fast acting oxidant if the pH is low. We lowered the dough pH to 5.0 by adding lactic acid to the dough water. Under those conditions  $\text{KBrO}_3$  appear to be no better than when used at the normal flour-water pH of 6.0.

A number of other formula variants were studied. The addition of 0.5% enzyme active soy flour appears to give a minor increase in volume but no other effects. Cysteine is often mentioned as a short-time dough additive. At 40 ppm cysteine, specific volume was decreased to 3.9 and the loaf was very poor. Small amounts of cysteine added with higher levels of  $\text{KBrO}_3$  were not as detrimental but gave no apparent advantage over  $\text{KBrO}_3$  alone. Cysteine cannot be used with fast acting oxidants as they interact during mixing. Small amounts of vital wheat gluten gave no apparent advantages. The same was true for yeast food and protease enzymes.

To produce continuous bread similar to that produced by the U.S. baking industry, we used a brew procedure. To produce bread similar to that produced in industry, we used a 30 ppm ADA, 7% sugar (2% in brew and 5% in dough), and a mixer rpm of 125. This gave us reasonable bread, very similar to commercial continuous bread grain. The grain, however, was inferior to that obtained by our short time continuous mix system.

#### RSM Study

Preliminary work had shown that yeast level and the level of oxidants in the dough was of particular importance in the continuous procedure. It is well-known in the baking industry that short-time and continuous systems require relatively high levels of fast-acting oxidants. Thus, a 5 level, 3 variable response surface (RSM) study was designed and carried out. The 3 variables were yeast, azodicarbonamide (ADA), and

potassium bromate ( $\text{KBrO}_3$ ). The levels of each variable were: yeast 3, 3.4, 4.0, 4.6, and 5%; AOA 0.0, 6.1, 15.0, 23.9, and 33.0 ppm; and  $\text{KBrO}_3$  45.0, 51.1, 60.0, 68.9, and 75.0 ppm. All values are based on the flour weight.

The responses evaluated were specific volume (loaf volume divided by loaf weight), crumb grain evaluated subjectively on a scale of 1 (poor grain) to 5.0 (excellent), and the degree of keyholing or shrinkage of the loaf. The degree of keyholing was determined by measuring the width of the loaf at 4.0 cm from the bottom of the pan. The value obtained was subtracted from the width of the pan at that height. Thus, a small value in cm indicates no keyholing and a large number indicates a large degree of keyholing.

The baking results were obtained with the continuous baking procedure as described previously. The RSM design called for 20 runs and included 6 runs at the center point of the experiment. The experimental doughs were run at random. The data obtained are given in Table 6.

Statistical analysis of the data gave the following equation for the specific volume response:  $y = 2.554 - 0.9354x_1 + 0.1891x_1^2 + 0.1755x_2 - 0.0011x_2^2 - 0.1019x_3 - 0.0004x_3^2 - 0.0127x_1x_2 + 0.0369x_1x_3 - 0.0005x_2x_3$  where  $x_1$  = yeast concentration in %,  $x_2$  =  $\text{KBrO}_3$  in ppm, and  $x_3$  = AOA concentration in ppm, all based on flour weight. The  $R^2$  was only 0.56, therefore, the fit of the data was not good. However, the surface obtained shows that specific volume increases as yeast and AOA were increased and  $\text{KBrO}_3$  was decreased. Optimum specific volume was predicted to occur at 5% yeast, 30 ppm AOA, and 45 ppm  $\text{KBrO}_3$ . No data point was at that point of our design. However, those points near that point, i.e., 5% yeast, 15 ppm AOA, and 60 ppm  $\text{KBrO}_3$ ; and 4.6% yeast, 23.9 AOA and 68.9  $\text{KBrO}_3$  gave good agreement

Table 6. Baking Data for the RSM Study of Yeast, AOA, and  $\text{KBrO}_3$ 

Run #	Yeast	AOA	$\text{KBrO}_3$	Specific Volume	Crumb Grain	Keyholing
	%	ppm	ppm	cc/g		cm
1	4.0	15.0	60.0	6.00	4.00	1.10
2	4.0	0.0	60.0	5.57	3.00	0.67
3	3.4	6.1	68.9	5.03	4.00	0.85
4	4.6	6.1	51.1	5.59	3.00	0.57
5	4.6	23.9	68.9	5.56	4.00	2.25
6	5.0	15.0	60.0	6.08	3.50	1.70
7	4.6	23.9	51.1	6.08	4.00	2.00
8	3.0	15.0	60.0	5.51	4.00	2.05
9	3.4	6.1	51.1	5.14	2.00	0.75
10	3.4	23.9	68.9	4.59	3.50	3.50
11	4.0	15.0	60.0	5.39	4.00	1.53
12	4.0	30.0	60.0	5.44	3.50	3.13
13	4.0	15.0	60.0	5.41	4.00	2.40
14	4.0	15.0	60.0	5.13	3.50	0.83
15	4.0	15.0	60.0	5.00	4.00	1.90
16	4.6	6.1	68.9	4.82	3.00	1.57
17	4.0	15.0	45.0	5.38	4.00	1.35
18	4.0	15.0	45.0	5.61	4.00	0.95
19	3.4	23.9	51.1	5.23	3.00	2.03
20	4.0	15.0	75.0	5.31	4.00	1.00

between actual and predicted values. It is strongly suggested from the data that as yeast increases more AOA is needed. This relationship was not obvious before the RSM study was run. The specific volume predicted at the optimum point was 6.83 cc/g or much higher than the center point of 5.43 cc/g.

The Taylor expansion equation for the response of crumb grain was as follows:  $y = -20.8197 + 6.043x_1 - 0.372x_1^2 + 0.3529x_2 - .0005x_2^2 + 0.1447x_3 - 0.0039x_3^2 - 0.0585x_1x_2 + 0.0351x_1x_3 - 0.0024x_2x_3$  where  $x_1$  = yeast concentration in %,  $x_2$  =  $\text{KBrO}_3$  concentration in ppm, and  $x_3$  = ADA concentration in ppm, all based on flour weight. The  $R^2$  was 0.72, somewhat better than that with specific volume. Optimum crumb grain scores were predicted at low yeast (3%), low AOA (9 ppm), and high  $\text{KBrO}_3$  (75 ppm) and at high yeast (5%), high AOA (30 ppm) and low  $\text{KBrO}_3$  (45 ppm). Actual data points were not taken at either of those points. The latter of those two points is also quite close to the optimum predicted specific volume which would indicate that optimum volume and crumb grain could be obtained at the same point.

The third response measures was keyholing or the degree of shrinkage. The Taylor expansion equation describing the surface for keyholing was as follows:  $y = -0.4454 - 2.581x_1 + 0.4375x_1^2 + 0.1735x_2 - 0.0012x_2^2 + 0.1339x_3 + 0.0021x_3^2 - 0.0074x_1x_2 - 0.0425x_1x_3 + 0.0010x_2x_3$ , where  $x_1$  = yeast concentration in %,  $x_2$  =  $\text{KBrO}_3$  in ppm, and  $x_3$  = ADA in ppm, all based on flour weight. The  $R^2$  for the surface was 0.75 indicating a good fit of the data. Minimum degree of keyholing was found at about 3.5% yeast, 0 ppm AOA and 45 ppm  $\text{KBrO}_3$ . Although no data point was obtained at the above location, at 3.4% yeast, 6.1 ppm AOA and 51.1 ppm  $\text{KBrO}_3$  the actual keyholing was 0.75 cm or only slightly above the predicted 0.68 cm.

Unfortunately, the conditions that gave our minimum keyholing also gave very poor specific volume and crumb grain. At the points identified to give good specific volume and good crumb grain, the keyholing is predicted to be 2.16 cm, or rather severe shrinkage. No actual data points were obtained at this point. It is obvious that a compromise is necessary to obtain a loaf of bread with good specific volume, crumb grain and a small amount of keyholing.

Close examination of the RSM data shows that bread with good specific volume, good crumb grain, and relatively small keyholing is only obtained with high yeast levels. As shown in Figure 26, the RSM model predicts specific volumes greater than 6.0 with crumb grain scoring above 4.0 and keyholing of less than 1.5 cm at 5% yeast with relatively low levels of  $\text{KBrO}_3$  (45.0 ppm) and moderately high levels of ADA (16 ppm).

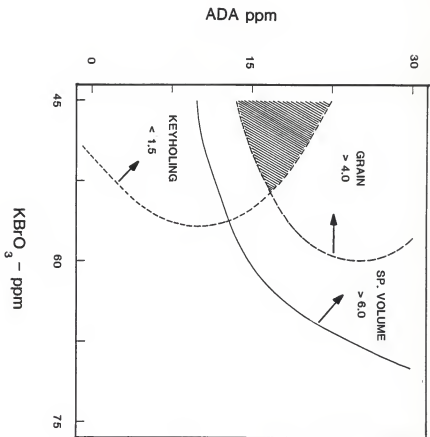
Confirmation runs were made to confirm the predictions made by the RSM study. For example, at 5% yeast, 30 ppm ADA and 60 ppm  $\text{KBrO}_3$  we obtained a specific volume of 6.1 somewhat lower than the prediction of 6.5. The crumb grain of 4.0 was slightly better than the 3.7 predicted and the degree of keyholing of 1.1 cm was much better than the predicted 2.8 cm. Thus, bread with good volume, grain, and degree of keyholing can be produced at high yeast levels (5%) and high levels of oxidants (30 ppm ADA and 60 ppm  $\text{KBrO}_3$ ).

#### Comparison of No-Time Continuous Bread with Conventional (Brew) Continuous Bread.

To compare the properties of no-time continuous bread with that produced with a conventional brew system, we employed sensory evaluation of the bread and a method to measure the firmness. Thus, the two important parameters of taste and firmness are being evaluated.



Fig. 26. Contour plot giving the response of specific volume, grain and degree of keyholing as a function of  $\text{KBrO}_3$  and ADA with the yeast level held constant at 5%.



The taste results showed no significant difference between the breads made by the two methods (Table 7). The test was run with untrained panel and, of course, it is problematical if a trained panel would have given similar results. We used the untrained panel because we felt the general public would not be attuned to the finer points of evaluating bread flavor. The degree of difference indicated by those judges who correctly identified the samples was only slight to moderate. Thus, those judges who were able to make the correct identification did not consider the differences marked. Similar results were shown by Redfern et al (1968). These workers found that a panel was unable to distinguish flavor differences of continuous mix bread made with a normal 2.5 hr brew and bread made with unfermented brew.

Bread made by the brew method was significantly softer one day after baking and remained softer during the 3 day test period (Table 8). It is not clear why the brew method would give softer bread. However, it is widely believed in the industry that no-time bread firms at a faster rate than does bread made by conventional process.

#### CONCLUSIONS

The optimum formulation used in the short-time system was found not to be suitable for the continuous mix process. In this process, doughs containing a combination of ADA (15 ppm) and  $\text{KBrO}_3$  (60 ppm) gave loaves with excellent grain. However, with the new oxidant system, two new problems were found. Those were keyholing and a dull, light brown crust color. To solve the color problem, the formulation was changed to include 6% sugar and 2% NFDM. From the RSM study, we concluded that bread with good volume, grain, and only moderate keyholing can be produced at high yeast levels (5%) and high levels of oxidants (30 ppm

Table 7. Results of triangle taste test.

Judges	Number		Significance level <sup>a/</sup>
	Correct	Incorrect	
32	12	20	N.S.
32	11	21	N.S.

<sup>a/</sup>Correct identifications necessary for significance 5% (16), 1% (18), and 0.1% (20).

Table 8. Firmness of bread made by no-time continuous and conventional (brew) continuous bread.

	Day 1		Day 2		Day 3	
	Brew g	No-time g	Brew g	No-time g	Brew g	No-time g
Trial 1	122	182	198	260	236	318
	123	169	196	291	268	350
	122	180	188	287	251	340
Trial 2	125	185	210	271	275	342
	124	170	190	260	256	329
	129	182	213	287	280	336
Mean	124	178	199	276	261	336
S.D.	2.64	6.78	10.3	14.2	16.5	11.1

ADA and 60 ppm  $\text{KBrO}_3$ ). We compared the difference between no-time continuous bread and conventional (brew) continuous bread. The results obtained from a panel test showed no significant difference.

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SHORT-TIME BREADMAKING SYSTEM

by

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the  
requirement for the degree

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## ABSTRACT

In studying the short-time breadmaking, the formulation was optimized to: flour (100%), yeast (5%), sugar (3%), salt (1.5%), shortening (3%), water (optimum), and the oxidants (100 ppm ascorbic acid and 60 ppm  $\text{KBrO}_3$ ). With that formulation, the fermentation time was reduced to 15 min, and the total time used in this baking system was shortened to about 100 min. Using the spread test to study the rheological changes of doughs with the short-time baking systems, it was found that yeast and oxidants interacted to effect dough rheology. Oxidants were found to have the greatest effect on gas retention. With the continuous mix process, the formula was adjusted by changing the oxidation system to 15 ppm AOA, 60 ppm  $\text{KBrO}_3$  and increasing the sugar to 6% and adding 2% NFDM. From a RSM study, we found that 5% yeast, 30 ppm ADA, and 60 ppm  $\text{KBrO}_3$  were optimum for continuous mix process. A taste panel found no significant difference for bread made with a no-time continuous process and a conventional (brew) continuous process.